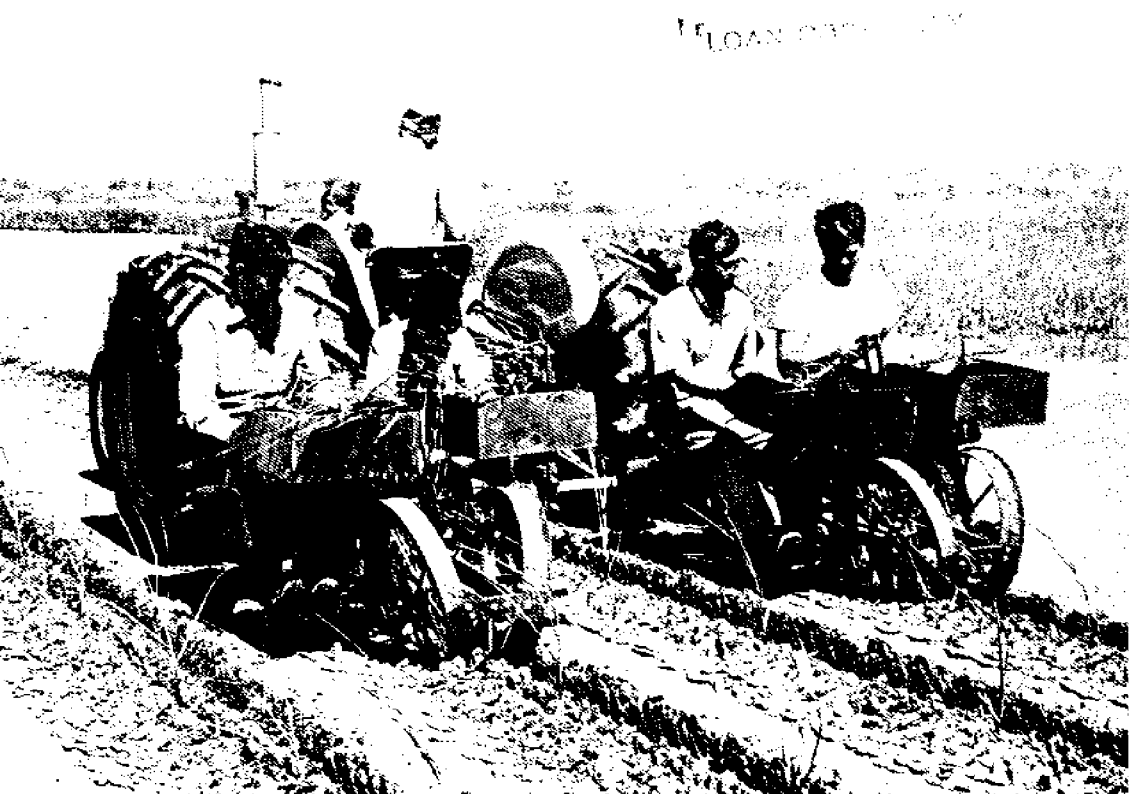


MARSH BUILDING WITH DREDGE SPOIL IN NORTH CAROLINA



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MARSH BUILDING WITH DREDGE SPOIL IN NORTH CAROLINA

W. W. Woodhouse, Jr., E. D. Seneca and S. W. Broome¹

Introduction

The value of tidal marsh for shoreline protection and as a nursery ground and source of energy for a high proportion of our commercial and sports fishery species has become widely recognized in recent years (Odum, 1961; Teal, 1962; de la Cruz and Odum, 1967; Cooper, 1969; Williams and Murdock, 1969). However, the acreage of this valuable habitat has been, until recently, shrinking at a rapidly increasing rate, largely through man's activities. Consequently, steps are being taken by the State and Federal governments to protect such areas from further damage.

It would seem highly desirable if a means could be developed for establishing new marsh to replace some of that which has been lost. Dredge spoil, produced in the maintenance of navigation channels within the sounds and estuaries, would appear to be a logical place to start. The U. S. Army Corps of Engineers maintains approximately 1500 miles of such channels in North Carolina waters alone. Much of the material removed in this operation eventually finds its way back into these channels. Therefore, the possibility appears to exist of combining two desirable objectives in one operation — the stabilization of dredge spoil and the establishment of new tidal marsh. If successful, such a development should serve a useful purpose all along the Atlantic and Gulf Coasts, and would be of special interest to North Carolina in view of the extensive sounds and estuaries lying within this state. This is a progress report on a study initiated in the fall of 1969, designed to explore this possibility.

Primary emphasis was placed initially on smooth cordgrass (*Spartina alterniflora* Loisel) since this is the dominant species of the regularly flooded intertidal zone in North Carolina. It is considered to be the most productive marsh type and appeared to be the most likely to succeed in the intertidal zone on the areas available. Early in the study

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it was found that, although much work had been done on natural stands of this species, almost nothing was known about establishing new stands and only a few isolated attempts had been made to transplant it (Larimer, 1968). However, it should be pointed out that an ecological equivalent of *S. alterniflora* (*S. townsendii* H. & J. Groves) has been planted by public authorities and private landowners in Europe for many years to stabilize mudflats. This action is designed to reduce the source area for channel silting as well as to protect coastlines from erosion, and to help reclaim mudflats on behalf of agricultural interests (Ranwell, 1967).

Since little is known about the propagation of *S. alterniflora*, it was necessary to start at the beginning and work out detailed procedures. Consequently, the past two years were devoted to examining a number of aspects of the reproduction, propagation, establishment, and growth of this species. This work has resulted in some tentative conclusions which may be useful to others. Work is continuing along these and other lines which will be reported in more detail later.

Location and Description of Experimental Sites

Most of the field work to date has been conducted at the following sites:

Location	Substrate*	Tidal regime
Oregon Inlet	Sandy — natural accretion; % sand — 97, % silt — 1.0, % clay — 2.	0.5-1.0 ft lunar with extensive wind effect
Dredge Islands along Old House Channel in Pamlico Sound	Both fresh and old sandy dredge spoil	0.5-1.0 ft lunar with extensive wind effect
Hatteras Inlet, Ocracoke side	Sandy — natural accretion and dredge spoil; % sand — 97, % silt — trace, % clay — 2.	More lunar (1.0-1.5 ft) than Oregon Inlet, but still large wind effects
The Straits, Harkers Island	Sandy to very fine fresh spoil; % sand — 76-93, % silt — 2-14, % clay — 4-10.	1.5-2.0 ft — lunar dominated with substantial wind effect
Snow's Cut — Dredge Island in Cape Fear River 15 miles upstream from Southport	Sandy to fine fresh spoil; % sand — 96, % silt — 1, % clay — 3.	4 ft lunar with little wind effect

* Analyses by hydrometer method (Day, 1956).

These areas were selected to provide a reasonably good cross-section of tidal and spoil conditions existing within the North Carolina sounds and estuaries. Plans are being made to expand the work to additional sites in the future.

Methods

Established procedures were not available for most of the field experimentation. Consequently, the methods are still in the process of development. Some replicated field tests have been established, but unreplicated plantings were made in a number of cases in order to get observations under as many conditions as possible.

Seeding plots were kept small, usually 4 ft x 30-50 ft, due to the limited amounts of seed available.

Transplants were spaced 3 ft x 3 ft in most plantings, using three-row plots and extending them various distances up and down the natural slopes of the sites. Transplants consisted of single stems, as shown in Fig. 13.

Data have been taken on dry weights of tops, roots, and rhizomes, on rate of spread of individual plants, height and number of flowers. Variability and the resulting experimental errors are, as might be anticipated, quite high in this work. Consequently, it is necessary to allow for a substantial amount of attrition in planning experiments and to recognize that only fairly large differences can be detected. Plant and soil samples for chemical analyses, which will be reported elsewhere, were handled by standard procedures.

Results and Discussion

Seeding *Spartina alterniflora*

It was observed that this species usually invades new areas by seed and at times is a heavy seed producer. Since direct seeding of most species, where feasible, is usually much cheaper than transplanting, this aspect has been given considerable attention.

Seed Production

Fairly heavy seed crops have occurred locally along the North Carolina coast in each of the last two years. In every case the best production was found in young stands. Evidently, as stands thicken and age, seed production drops sharply and may be largely confined to

edges along creeks or disturbed sites. Taylor (1938) observed that thick stands of *S. alterniflora* on Long Island, New York did not flower.

Seed Harvest

Seeds mature along the North Carolina coast from North to South from mid-September to about mid-October and maturity is quite variable even within individual stands. Consequently, degree of maturity within seed lots is quite variable, which undoubtedly affects subsequent seed quality and performance. Seeds must be harvested shortly after maturity, before they shatter. Consequently, date of harvest must be carefully timed if any significant part of the crop is to be saved.

Harvesting the first year was done by hand, plucking individual seedheads (Fig. 1). This was extremely slow and laborious, and provided a very limited supply of seed. Consequently, in 1971 we undertook to mechanize the operation, assembling a "harvester" on a 2-wheel garden tractor (Fig. 2). Although rather crude, this turned



Fig. 1. Hand-harvested *S. alterniflora* seeds, showing plucked heads and shattered seeds.



Fig. 2. Seed harvester operating in a *S. alterniflora* marsh at Oregon Inlet.

out to be a big improvement. It can be operated over the marsh by one man, and speeds up harvesting about five-fold. We now have enough seed to plant several acres.

Storage

Seeds lose their viability rather rapidly when dried. Storage in sea water at 35-38°F is the most satisfactory method tried so far. Storage at these cool temperatures is essential to delay germination until seeding time. Germinability of seeds is very low immediately after harvest, but increases sharply over a 2 to 3 month period as, what we assume to be, some type of after-ripening process proceeds (Fig. 3). The lower curve in Fig. 3 describes germination for seeds harvested September 28, 1971, stored moist in the cooler until threshing October 19, and placed in the germinator October 20. The upper curve describes germination for seeds harvested on the same date and stored in cold sea water until January 21, 1972. The differences are rather striking with less than 60 percent germination spread over a 30-day

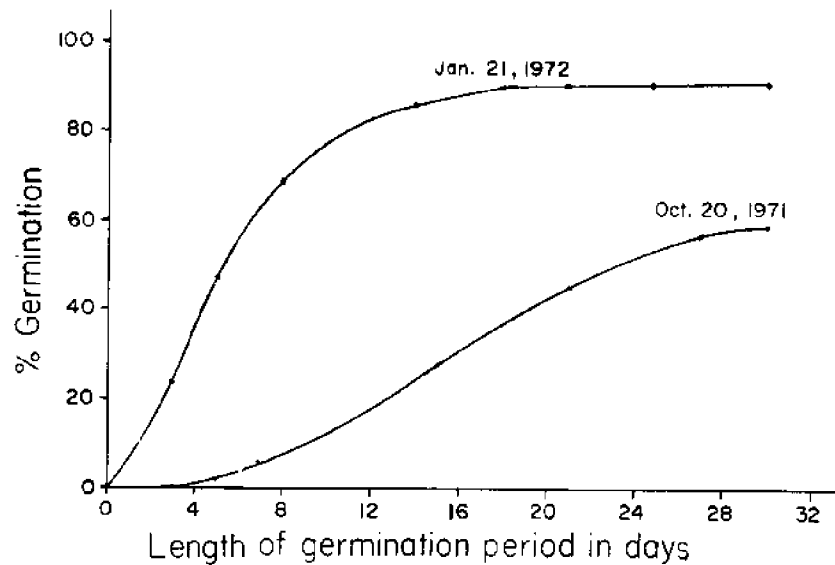


Fig. 3. Effect of after-ripening on germination of *S. alterniflora* seed.

period for the fresh seed vs 80 percent germination within 12 days in the case of seeds permitted to after-ripen for 90 days. The rapid germination of the latter lot would obviously be highly desirable in the establishment of this species on a new area.

Planting

Although seed germinate over a wide elevation range, young seedlings survive in appreciable numbers in a rather narrow zone near the mean high water line (Fig. 4). Plants have been established from seed on spoil in each of the last two years. The principal problem appears to be that of keeping seeds in place until they can germinate and become established. They need to be covered to a depth of $\frac{1}{2}$ to 1 inch, and any method that will accomplish this—discing, raking, harrowing, etc.—seems to be satisfactory (Fig. 5).

Germination begins in March, but better luck was had with April seedlings which avoid some of the stormy weather and are, consequently, less subject to excessive erosion or deposition.

Confining the seeds to "drill" rows does not appear to be as desirable as some kind of "broadcast" placement because seedlings remain confined to the rows the first year; however, they do populate the "middles" the second year (Fig. 6).

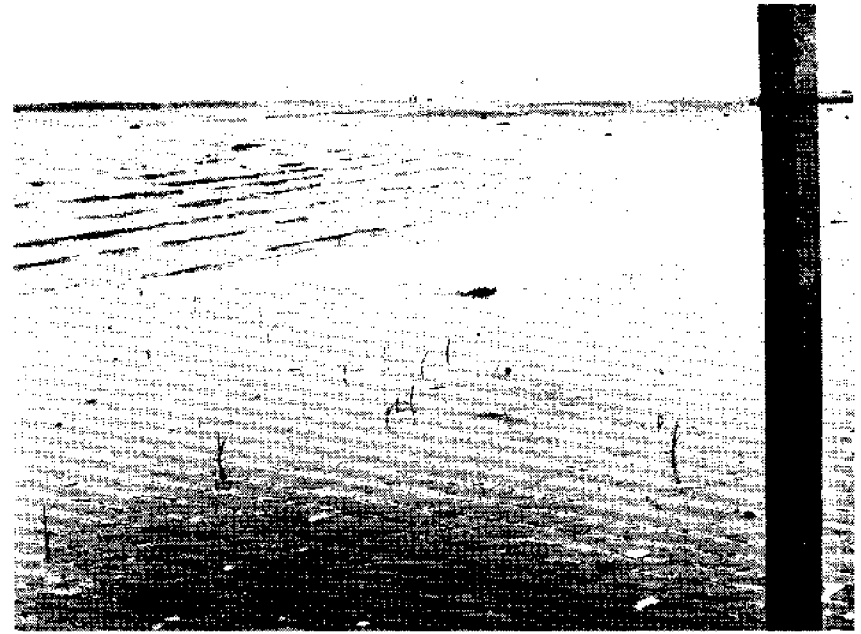


Fig. 4. Natural *S. alterniflora* seedlings at Snow's Cut; germinated late March; photo April 27, 1971.

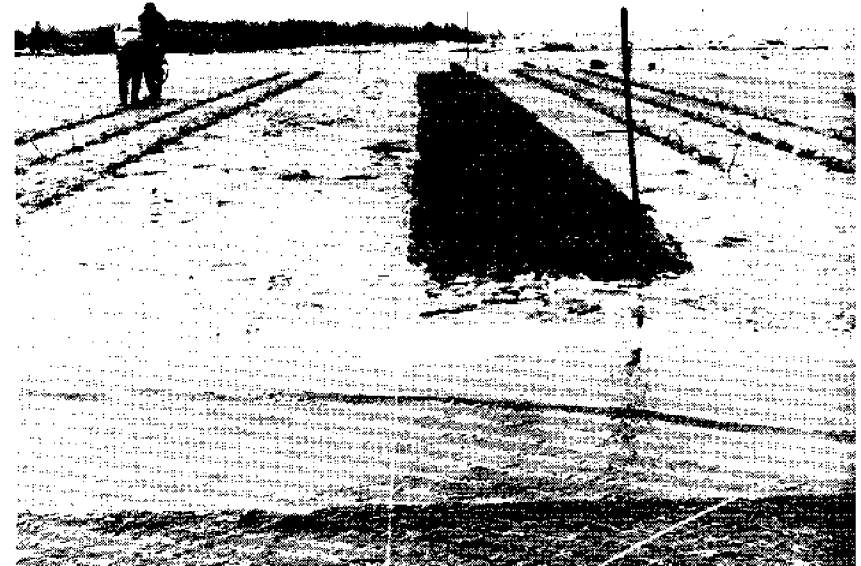


Fig. 5. *S. alterniflora* seed raked in (right center), applied in a clay slurry (upper left center).



Fig. 6. Seedling growth of *S. alterniflora* from row planting, Oregon Inlet. (Left) Seeded April 21, 1970, photo Sept. 14, 1970. Same plants (right) Sept. 1, 1971. Note growth in spite of very severe grazing by snow geese, winter of 1970-71.

After an initial period of slow growth, which lasts into June, surviving seedlings grow quite rapidly, very nearly "catching up" with transplants in height and far exceeding them in cover. For example, the best top growth of transplants at Snow's Cut was 289 gms/yd² while the best seedling growth was 808 gms/yd² (Fig. 7). The seedlings were not as tall but their dense stand completely covered the surface. Therefore, we feel that direct seeding is, indeed, a promising procedure for the establishment of this species on areas having suitable elevation, and sufficient stability during the period April through June.

"Natural" Seeding

New areas are at times taken over rather rapidly by seedlings of this species when the required combination of factors occurs. It appears that seed supply is often a limiting factor and that the establishment of small patches of *S. alterniflora* by transplanting might be effective in supplying seed to the surrounding area. Seedlings were observed in 1971 on two rather isolated islands in Pamlico Sound on which "seed patches" were transplanted in 1970, and on which no *S. alterniflora* existed prior to that time.



Fig. 7. First-year growth of seedlings at Snow's Cut, seeded March 24, 1971; photo Sept. 14, 1971.

Transplanting Spartina alterniflora

Although direct seeding holds considerable promise for certain situations, transplanting of growing plants is almost certain to be the principal method of establishing this species on most spoil areas. Consequently, an effort was made to identify the major factors involved.

Obtaining Plants

Plants have to be "dug" from established stands. Digging and separation of stems is much easier from young stands growing on sandy substrates. The thick mat of roots and rhizomes that develops near the surface of older marsh makes it very difficult to extract planting material.

Plants should be separated into single large stems (small stems left attached or discarded), and kept moist until transplanted. They can

be stored for periods of several days by heeling-in within the intertidal zone, but care should be taken not to exclude light from the tops. Some pruning of tops is desirable where growth is excessive, but severe defoliation can be very detrimental to survival.

Gathering plants is, by far, the most time-consuming step in the transplanting operation, and mechanization would be highly desirable. Plans are to try a small back-hoe on this in 1972.

Transplanting Method

Hand planting involves opening a hole with a dibble and inserting a single healthy culm (stem) to a depth of 4-6 inches and firming the soil around it. Men work in pairs, one opening holes and the other planting (Fig. 8). Planting depth has not been studied since we found it impractical to undertake to plant much deeper than about 5 inches due to the difficulty of keeping the hole open until the plant can be inserted. Also, it appears that in this environment, planting depth, as long as it is not excessive, is of significance only in anchoring the plant until it can become established.

A small amount of machine planting was done, using our dune-grass transplanter. This appears to be quite practical on many sites and plans are to work on this extensively in the future (Fig. 9).



Fig. 8. Hand transplanting *S. alterniflora*.



Fig. 9. Mechanical planting.

Plant spacing was not varied a great deal. Most planting the first year was spaced 3 ft x 3 ft and this turned out to be a good compromise between cost and rate of stabilization. Under the best conditions, April transplants at this density form almost complete cover by the end of the first season, while under all but the worst conditions, cover is complete by the end of the second season (Fig. 10). For example, the January 5, 1970 planting at Oregon Inlet produced a mean top growth of only 45 gms/yd² in 1970, but by September 1971 these plots had a mean yield of 465 gms/yd².

Time of Transplanting

A replicated trial comparing transplanting dates was established near Oregon Inlet in November 1969, and a similar test in the same general area in the winter of 1970 (Tables 1 and 2). They show successful establishment of *S. alterniflora* at all dates—November through May—with significant differences in growth or stand survival due to

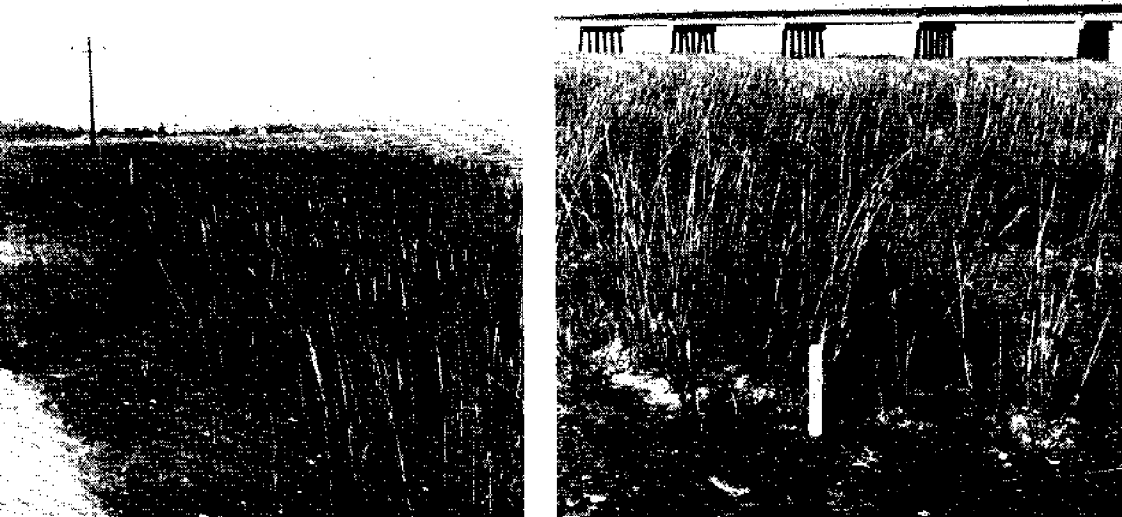


Fig. 10. Second-year cover from *S. alterniflora* transplanted 3' x 3'. (Left) The Straits, planted April 10, 1970; photo Sept. 2, 1971. (Right) Oregon Inlet, planted Jan. 5, 1970; photo Sept. 1, 1971.

time of planting. In the 1969-70 trial, first-year growth was larger from winter and early spring transplanting (December - March), but survival was more consistent with spring transplants. The better growth from early planting was expected since this allows for early root development and should get the plant off to an early start. In the 1970-71 trial, date of planting through the winter to mid-spring had little effect on total growth, but survival was better during spring.

Some of the differences between these trials were almost certainly due to site and storm effects differences. The 1969-70 experiment was in a fairly sheltered location. The 1970-71 test was quite exposed and was hit by several severe winter storms which doubtless affected the November through February plantings. This effect is seen in survival and may have reduced growth of the early plantings.

These two trials were supplemented by plantings at a number of other locations, some of which were extended well into the summer. In general, these plantings tended to confirm the findings cited above, with one important addition – survival of summer transplants was surprisingly high, generally better than those planted earlier in the year (Table 3, Fig. 11). Growth for that season was, of course, limited by the time available, but plants became well established (Fig. 12). At this point, we believe that this species can be transplanted with reasonable success from December through July. First-year growth

Table 1. Dry weight of shoots and percent survival for *S. alterniflora* based on September 1970 harvest of three plants in each of 3 replicates for eight transplanting dates

Transplanting Date	Shoot dry weight (grams/plant)	Percent Survival
November 6, 1969	9.8	74.1
December 8, 1969	30.3	98.8
January 5, 1970	23.8	94.5
February 3, 1970	21.0	89.9
March 2, 1970	12.3	72.7
March 25, 1970	15.9	94.0
April 23, 1970	15.2	91.7
May 25, 1970	13.9	97.7
LSD	.05	10.1
C.V. %	47	6.5

Table 2. Dry weight of shoots and percent survival for *S. alterniflora* based on September 1971 harvest of three plants in each of 2 replicates for eight transplanting dates

Transplanting Date	Shoot dry weight (grams/plant)	Percent Survival
November 10, 1970	27.3	29.7
December 12, 1970	30.2	36.7
January 6, 1971	18.5	44.0
January 25, 1971	38.5	49.5
February 22, 1971	35.7	42.3
March 31, 1971	25.7	71.3
April 23, 1971	25.8	58.5
May 5, 1971	28.8	67.5
LSD	.05	ns
	.01	ns
C.V. %	45.7	33.4

Table 3. Comparison of growth of *S. alterniflora* planted at four different dates in late spring on dredge spoil at Ocracoke. The figures are means of 4 individual plants collected September 1, 1971

Planting date	Height	No. stems/plant	No. rhizomes/plant	No. flowers/plant	Dry wt/plant	B.A. ^a ft ² /yd ²	% Survival
3-11-71	93.5	9.8	23.5	6.8	32.8	0.012	72.9
4-22-71	93.8	17.3	14.8	8.8	41.3	0.008	69.6
5-12-71	72.0	7.8	6.8	3.0	13.3	0.005	75.0
6-22-71	66.0	8.8	0.3	2.3	6.5	0.001	85.0
LSD	.05	19.8	5.6	ns	4.7	15.9	0.005
	.01	ns	ns	ns	22.3	0.007	
C.V. %	15.8	34.7	99.0	58.0	54.6	51.1	

^a Cross-section area of base of culms as clipped at ground surface.



Fig. 11. Growth of late spring and early summer transplants, Snow's Cut. Two rows on left planted June 2, 1971; single short row at right planted July 8, 1971; photo Sept. 14, 1971.

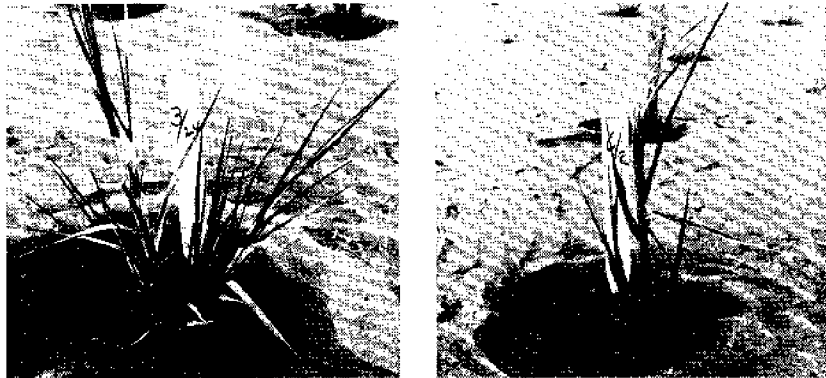


Fig. 12. Effect of time of planting on growth of individual plants, Snow's Cut. (Left) Planted March 24, 1971. (Right) Planted June 2, 1971. Photos July 8, 1971. Note much more growth from March planting but rapid establishment from the June planting (4 or 5 new shoots after only 5 weeks).

is likely to be substantially larger from stands established during the first half of this period, but the operation will generally be more efficient during the milder weather of the latter half, and survival will be improved. Therefore, most transplanting is being delayed until after the end of March in order to avoid the inefficiencies inherent in carrying out this kind of work during the rougher weather, as well as to reduce the storm hazard on newly transplanted areas.

Plant Source

Plants of this species along the North Carolina coast vary considerably in growth habit and vigor from site to site. Just how much of this is genetic and how much environmental is still a matter of debate. This variability could be a cause for concern in moving planting material from one location to another. In April 1971 five different types of transplants were gathered from locations as diverse as Oregon Inlet and Snow's Cut, and placed in a replicated experiment at Snow's Cut (Fig. 13).

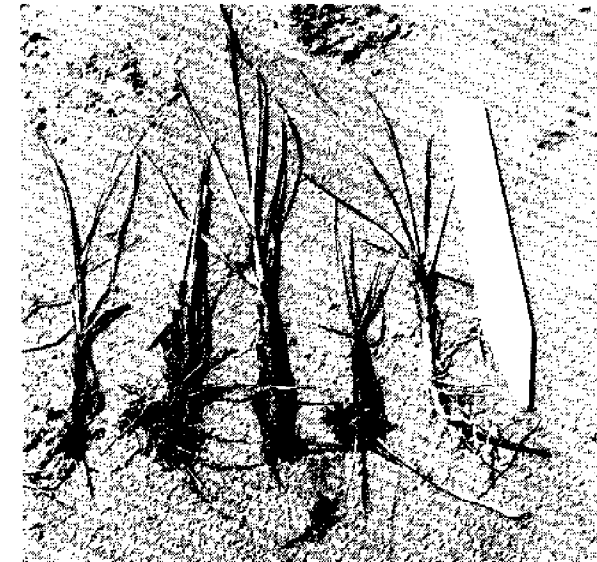


Fig. 13. Sources of *S. alterniflora* planting; stock-planted at Snow's Cut April 7, 1971. Left to right: Oregon Inlet, Hatteras Inlet, Beaufort tall, Beaufort short, Snow's Cut. For comparison, stake on right is 15 inches long.

Table 4. First-year growth of *S. alterniflora* transplants from different sources. Snow's Cut—planted April 8, 1971, sampled September 9, 1971

Source	Top growth gms/yr ² Avg 3 replications
Oregon Inlet	159
Hatteras Inlet	205
Beaufort — short height form	142
Beaufort — tall height form	237
Snow's Cut	272

Survival and first-year growth was excellent on all five (Table 4). They were still different in appearance at the end of the growing season, though less so than at the beginning and, therefore, will be followed with interest in succeeding years (Fig. 14). It would appear from this trial that planting stock might be safely moved from most any site to another, provided that the planting site represents similar environmental factors such as tide range and no higher salinity than that prevailing where the plants were dug. This stipulation as to tide range and salinity is suggested in view of the observation that plants from Snow's Cut did not do well when moved to Oregon Inlet (Fig. 15).

Elevation

It appears that transplants can be established successfully along the North Carolina coast throughout most of the intertidal range, at

Fig. 14. First-year growth of two sources of planting stock showing Beaufort short (left) and Beaufort tall (right); planted Snow's Cut, April 7; photo Sept. 14, 1971. Note tall height form is still much taller and more erect at end of first season.

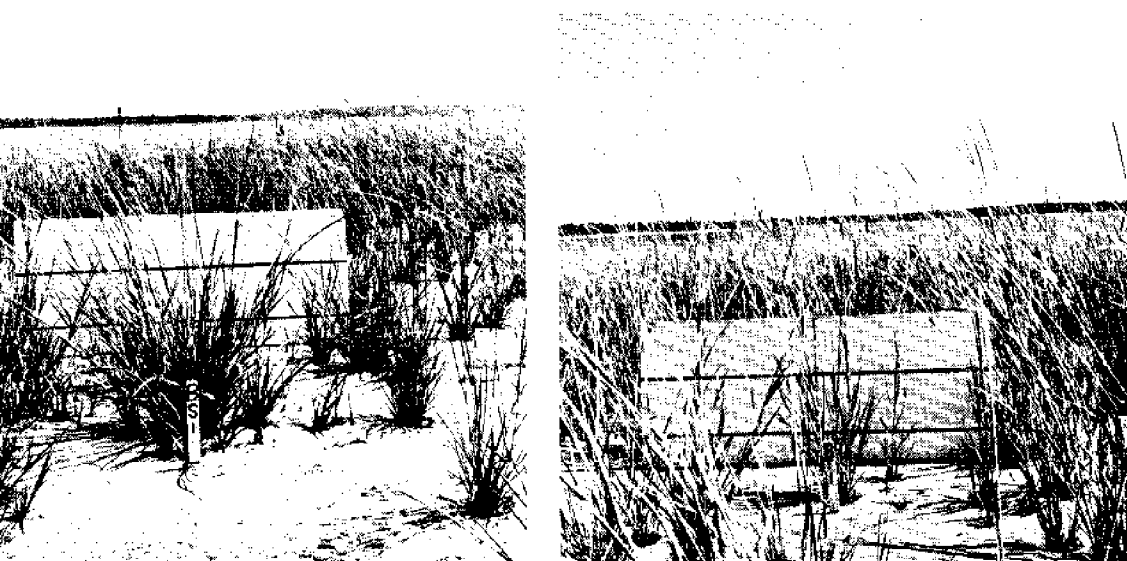


Fig. 15. Effect of moving planting stock from wide tide range—low salinity site (Snow's Cut) to wind tide—high salinity site (Oregon Inlet). Center 3 rows transplanted from Snow's Cut March 31, 1971. Plants to the left from Oregon Inlet; photo Sept. 1, 1971.

any given location. We have found at all sites studied a fairly definite elevation cutoff below which plants do not survive. There is generally a zone of best growth somewhat above this with the upper limit being ill-defined and overlapping the range of adaptation of other species (Fig. 16).

Estimates of these elevations are as follows.

Location	Zone	M.S.L. 1929 Datum
Snow's Cut	Lower limit of survival	-0.46
Snow's Cut	Lower limit of best growth	1.30
Snow's Cut	Upper limit of best growth	1.87
Snow's Cut	Upper limit of survival	3.30
Harkers Island	Lower limit of survival	0.20
Harkers Island	Upper limit of survival	2.40
Hatteras Inlet	Lower limit of survival	0.27
Hatteras Inlet	Upper limit of good growth	1.24
Hatteras Inlet	Upper limit of survival	1.50
Oregon Inlet	Lower limit of survival	0.68
Oregon Inlet	Lower limit of good growth	1.00
Oregon Inlet	Upper limit of good growth	1.30

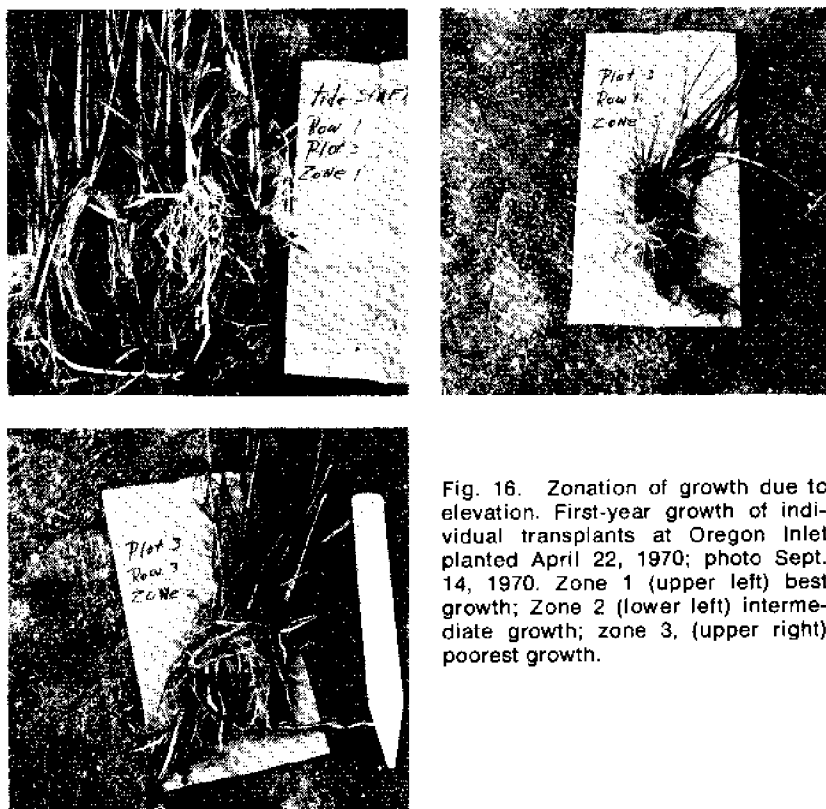


Fig. 16. Zonation of growth due to elevation. First-year growth of individual transplants at Oregon Inlet planted April 22, 1970; photo Sept. 14, 1970. Zone 1 (upper left) best growth; Zone 2 (lower left) intermediate growth; zone 3, (upper right) poorest growth.

Growth and survival over this range can likely be explained in terms of time of exposure and inundation when enough tide data from the right sites have been accumulated and properly analyzed. About two years' data have been collected from two sites and are being analyzed by the Coastal Engineering Research Center.

It is already apparent that, as might be expected, where the tide range is narrow the band of elevation within which this species can survive is correspondingly narrow. For example, *S. alterniflora* survives over an elevational range of about 1.25 ft at Hatteras Inlet versus nearly 3 ft at Snow's Cut.

Substrate

Transplanting has been successful on a fairly wide range of substrates, from coarse natural accretion at Oregon Inlet to some very fine fresh material at the Straits. Fair to excellent growth has been obtained on at least some portions of all these sites.

We are now seeing definite differences in growth and survival which appear to be due to substrate. The only case in which we have identified the cause has been at the Straits where salt concentration builds up to toxic levels in small areas. For example, salinities determined at this location were as follows:

Date	Sound water	Soil solution
July 28, 1971	28°/oo	32-58°/oo
September 9, 1971	32°/oo	35-80°/oo

Wherever the salinities of the soil solution exceeded 45°/oo die-back of *S. alterniflora* leaves was observed, and in more severe cases entire plants appeared dead. The reasons for the salinity build-up are not clear. We strongly suspect that it is tied up with the inter-layering of very fine and coarse sediments which occurs irregularly over this site.

There are other substrate effects that are large enough to be significant. These will warrant further study.

Nursery Production of Planting Stock

Obtaining transplants from nature has been by far the most difficult and time-consuming phase of the whole transplanting operation. Consequently, nursery production of planting stock could be well worth considering. This was tried in a preliminary way at the Central Crops Research Station at Clayton, just east of Raleigh, on a site that turned out to be considerably less than ideal (Fig. 17). Results there indicate that it is feasible, and if done on a field-scale, might result in considerable savings over obtaining plants in the conventional way. First-year growth fell between that on the best and worst coastal sites as can be seen in Table 5. We are confident that this could be easily improved upon by moving to a more suitable soil.

Certainly, digging and processing would be much easier, and planting stock should be more uniform. Primary requirements appear to be

Table 5. First-year top growth of individual transplants at different sites.

Site	Mean dry weight gms/plant
Snow's Cut zone of best growth	250
Snow's Cut upper zone	36
Snow's Cut lower zone	29
Oregon Inlet zone of best growth	79
Hatteras Inlet zone of best growth	33
Clayton Nursery	63



Fig. 17. Nursery production of *S. alterniflora* at Clayton, N. C. Plants from Snow's Cut, transplanted May 18, 1971; photo Nov. 5, 1971.

a soil with slow internal drainage, an ample water supply, and suitable irrigation equipment. As can be seen in Fig. 17, weed control can be difficult. This avenue may be well worth additional attention.

Stabilization

No measurements of the stabilizing value of these plantings have been made. However, evidence of accretion is apparent on many sites, and from the mass of roots and rhizomes (Fig. 18) that develop under these stands, it would appear that such cover would afford considerable protection, particularly from short-term, storm-induced erosion (Fig. 18).

Choosing Planting Sites

It will be difficult to work out any definite guidelines for choosing planting sites. This is due to the inability to accurately forecast degree and timing of erosion or deposition during the establishment period.



Fig. 18. Root and rhizome mass under 1/4 m² of *S. alterniflora* at end of second growing season, Oregon Inlet; planted 3' x 3' April 22, 1970; photo Sept. 1, 1971.

From our experience, it is apparent that, in North Carolina waters, some sites can be seeded and many can be transplanted, but that there are others where, due to rapid erosion or accretion, the establishment of vegetation is not immediately possible. Some of these more hazardous locations, such as some of the small spoil islands in Pamlico Sound, can be readily recognized because of their extremely exposed position. However, in most cases, it does not appear to be that simple. Occurrence, absence, or timing of the more severe storms in any given season may be decisive. On many sites vegetation can be established in favorable years, but not in others. In this respect, this will be much like our experience with dunes.

It is clear that seeding should be confined to the most protected sites, to a fairly narrow band of elevation, and to a fairly limited time span during the season. Transplanting on the other hand is much more adaptable as to site and can be done over a period of several months.

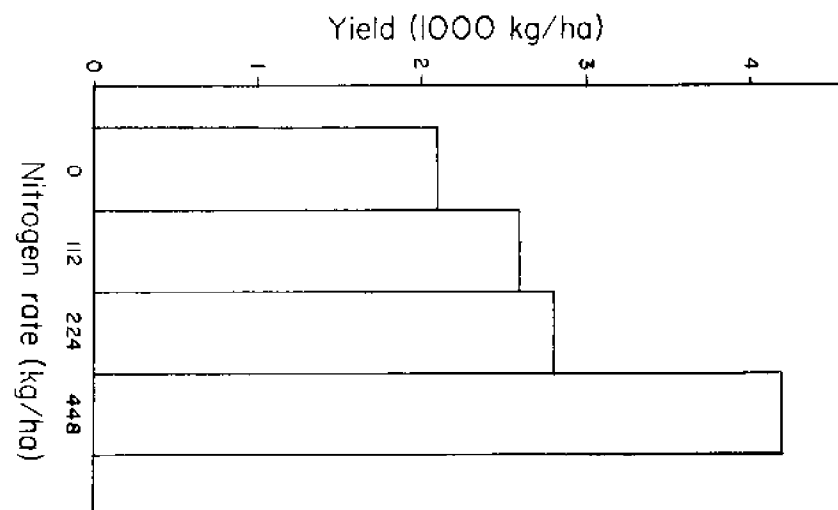


Fig. 19. Effect of nitrogen on yield of dry matter of *S. alterniflora*. N applied August 5, 1970; harvest Oct. 1, 1970.

Response to Fertilizer

There is strong evidence to indicate that nitrogen supply is limiting the growth of much *S. alterniflora* along the North Carolina coast and that phosphorus is limiting on some. Growth response in two tests is presented in Figs. 19 and 20. The 1970 test (Fig. 19) was initiated in midsummer on a young (2 or 3 years old) stand growing on sandy substrate. Response to N was probably as large as could be hoped for from such late treatment. The 1971 trial (Fig. 20) was initiated in the spring on a similar site and both N and P were found to be rather severely limiting. This appears to have implications for the possibility of these plants acting as a sink for nutrients which contribute to eutrophication of estuaries, as well as indicating something of their nutritional requirements. The question of the feasibility of using fertilizers to speed up stabilization will require further study.

Other Plants

Saltmeadow cordgrass, *Spartina patens* (Ait.) Muhl., was planted to overlap *S. alterniflora* at several sites. Survival and growth of *S.*

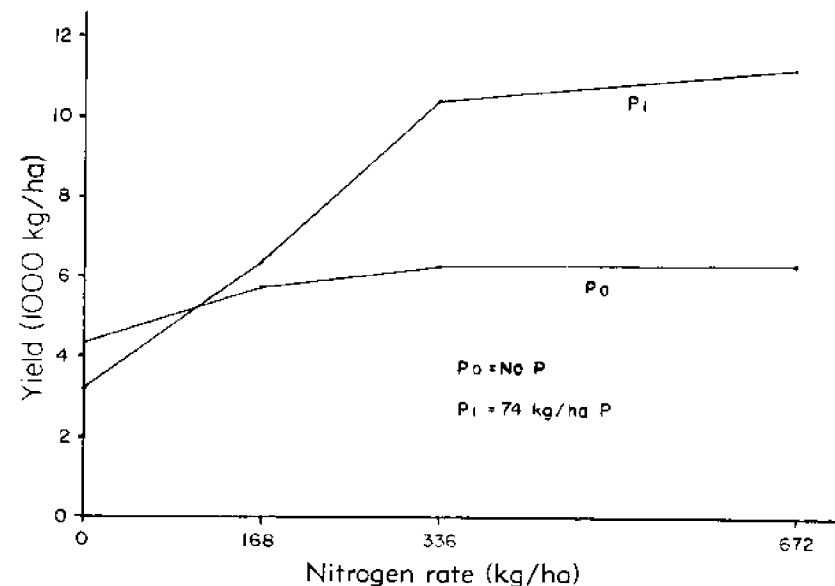


Fig. 20. Effect of nitrogen and phosphorus on yield of dry matter of *S. alterniflora*. Fertilizers applied in 3 equal parts in May, June, and July, 1971; harvest Sept. 1, 1971.

patens has been good, with a fairly sharp cutoff occurring on the lower end, near the upper edge of the zone of best growth of *S. alterniflora* (Fig. 21). Lower end cutoff was 1.92 (MSL 1929 datum) Oregon Inlet; and 2.06 (MSL 1929 datum) Snow's Cut.

Fig. 21. Two rows of *S. patens*. (Left) Extending down-slope into *S. alterniflora* planting, shows *patens* cut-off near upper edge of best growth of *alterniflora* and poor growth of latter above that point; photo Sept. 15, 1971. Snow's Cut. Same two rows (right) of *patens* extending upslope for another 150 yards; planted April 27, 1971.



In nature, *Panicum amarulum* Hitchc. and Chase appears promising for initial stabilization for spoil areas above the elevation of good growth of *S. patens* and it has the advantage of being direct seeded. Although we were late in getting it seeded and experienced a very dry June, we did get plants established on islands in Pamlico Sound and at Snow's Cut (Fig. 22).

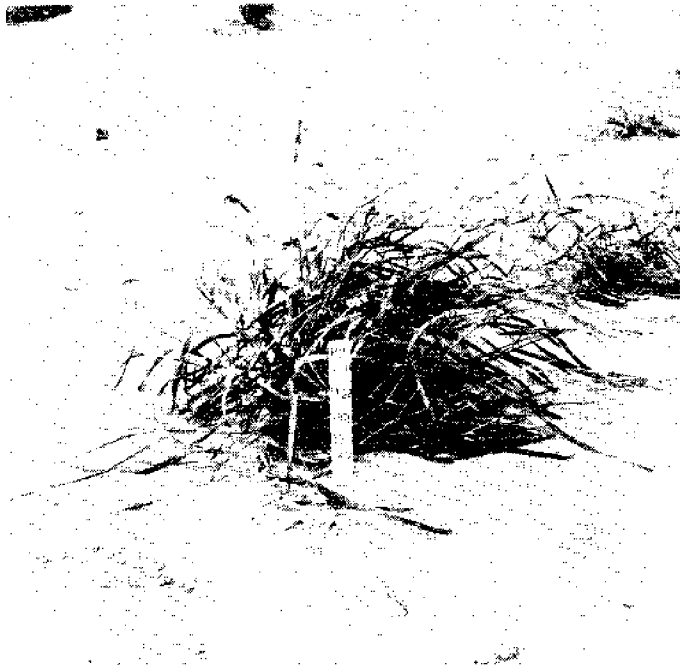


Fig. 22. *Panicum amarulum* seeded May 11, 1971; photo Sept. 22, 1971. Dredge Island, Old House Channel, Pamlico Sound.

Summary and Conclusions

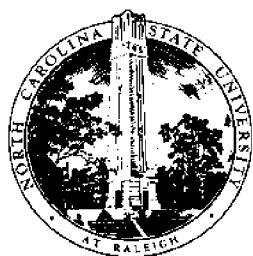
Work was initiated in the fall of 1969 along the North Carolina coast on the stabilization of dredge spoil with *Spartina alterniflora* Loisel. Studies included methods of propagation and establishment, growth rates, factors affecting growth, and substrate and elevational effects. Reasonably satisfactory methods and procedures have been developed and some tentative guidelines formulated for the use of this plant for stabilization of dredge spoil.

In conclusion, it was found that:

1. The establishment of new *S. alterniflora* marsh on some spoil areas is feasible with complete cover to be expected in two growing seasons.
2. Establishment of this species is possible by means of either seeds or transplants.
3. Direct seeding appears to offer a very rapid and relatively economical route to establishment on and stabilization of areas meeting certain standards.
4. Transplanting is adaptable to a much wider variety of conditions, but is likely to be considerably more expensive.
5. A great deal of work remains to be done on such things as nutrient requirements, substrate effects, tidal effects, planting stock supply, and the development of larger scale, more mechanized procedures.

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